JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINE

Chemical, Biological, Radiological and Nuclear (CBRN) Injury Response Part 3: Medical Management of Radiation Exposure and Nuclear Events

This guideline is intended for use with Tactical Combat Casualty Care Guidelines as an organized approach to the care of CBRN casualties.

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CLINICAL SCENARIO

You are on a humanitarian mission working in a hospital built in the 1960s. Theft is a common problem at this hospital. The hospital experienced a large robbery 1 week ago. The pharmacy, radiology, treatment areas and the lab had many items stolen.

A family of four presents to the hospital. The father was one of the hospital guards. He arrived with a full thickness hand burn. The family also had:

- Nausea/vomiting for 1 week
- Bloody diarrhea
- Dizziness
- Fatigue

Lab evaluation: Pancytopenia

What is this agent?

a. Chorine gas
b. Radiation exposure
c. Sarin gas
d. Mustard gas

INTRODUCTION

This document is part three to the CBRN clinical practice guideline (CPG) series. It provides guidance for the recognition, decontamination, treatment, and triage of suspected or confirmed irradiated and/or contaminated patients.

Since Level 1 evidence does not exist to guide the management of these casualties, the subject matter experts (SMEs) who drafted this CPG used references, best medical advice, and historical precedents to develop guidelines for the management of this unique patient population. This CPG can be used in conjunction with the Medical Management of Radiological Casualties Handbook. Reach back and consultation is available 24/7/365 with Armed Forces Radiobiology Research Institute (AFRRI) SME at 301-295-0530 by requesting the Medical Radiobiology Advisory Team.

When you suspect radiation exposure or a wartime or environmental nuclear event: [1]

1. Notify your chain of command immediately.
2. Set up separate triage and clinical care areas for management of these casualties.
3. Record as much clinical data as possible in the medical record.
    a. Document time of exposure
    b. Document exposure time (duration of exposure)
    c. document % TBSA if burn is present
    d. document any PPE that the casualty was wearing
    e. document initial symptoms and time that the symptoms started
4. Call AFRRI (301-295-0530) and request the Medical Radiobiology Advisory Team for clinical guidance or Radiation Emergency Assistance Center/Training Site (REAC/TS), 865-576-1005.
5. Submit all clinical records to the Joint Trauma System (JTS) so rapid performance improvement (PI) can be conducted to develop evidence-based clinical practice guidelines.

HISTORIC CASE EXAMPLE: SETTING THE CONTEXT

THE SETTING: Sept 13, 1987, Goias, Brazil

- Radiotherapy source stolen from abandoned hospital
- 249 people were contaminated / 4 died
- ~ 112, 000 people were examined for radioactivity
- One of the world's worst nuclear disasters

CLINICAL CONCERNS FOR EXPOSURE

- Radiotherapy source stolen from abandoned hospital
- 249 people were contaminated / 4 died
- ~ 112, 000 people were examined for radioactivity
- One of the world's worst nuclear disasters

- **Location** of patient in relation to device or epicenter
- **Duration of time** the patient was exposed to radiation
- **Shielding** between patient and the radiation source
- **Type of Radiation** the patient was exposed to

ALPHA particles ✦ BETA particles ✦ GAMMA rays

TYPES OF RADIATION

α particles / rays - unable to penetrate skin; PPE protects

- 2 protons & 2 neutrons → heaviest radiation particles
- Uranium, Radium, Radon
- Harmful if ingested, inhaled → ionizing cell damage

β Particles – moderately penetrating but PPE protects.

- Particles can travel a few meters in air
- Electrons ejected from a radioactive atom
- Hydrogen-3 (Tritium), Carbon-14, Sulfur-35
- Harmful external and internal exposures

Rays – electromagnetic radiation can travel meters

- Require dense material (lead) to shield
- High energy phones emitted by radioactive decay
- Exposure internally or externally is harmful

SYNDROMES

Bone Marrow Syndrome

- Symptoms secondary to pancytopenia
- Fatigue, bleeding, infection

Gastrointestinal Syndrome

- Anorexia, nausea, vomiting diarrhea,
- Severe dehydration, electrolyte imbalance
- GI bleeding

Cardiovascular/ CNS Syndrome

- Extreme nervousness, confusion, loss of consciousness
- Burning sensation of skin
- Watery diarrhea, seizures, coma

TREATMENT

- HAVE AN INDEX OF SUSPICION!
- Treat any trauma/burns
- CBC, follow WBC
- Check HLA type prior to transfusion
  → Stem cell transplant/transfusion
- Supportive care
- Viral prophylaxis
- Consult! Hematology and radiation experts

RADIATION BASICS

Anxiety and fear associated with radiation emergencies is often out of proportion to the degree of radiation-induced health effects.

Radiation and radiation injury are complex; however, two important concepts facilitate understanding: radioisotopes and ionization The first, radioisotopes (also called isotopes or radionuclides are the physical substances which release ionizing radiation as they decay. These radioisotopes can be toxic on their own without consideration to their radioactivity (or ability to release ionizing radiation). Radioisotopes can be found in any physical state (solid, powder, liquid, vapor, gas, even salts or other compounds). The second concept to understand is ionizing radiation. This is the "irradiation" portion of radioisotopes. Ionizing radiation is the invisible dose of energy that causes biological damage. This damage only occurs when exposed to a radioisotope.[2]

Four potential sources of radiation injury are:

1. Irradiation (no contamination, similar to an x-ray exposure).
2. External contamination (a radioisotope physically present on the patient that may also be irradiating the patient).
3. Internal contamination (a radioisotope has been inhaled, ingested, or injected into the patient: the radioisotope may also be irradiating the patient internally).
4. Incorporation (uptake of the radioisotope into the cells or tissue: in addition to the potentially heavy metal poisoning, the radioisotope is irradiating the patient internally).

Ionizing radiation is radiation that has enough energy to detach electrons from atoms, creating ions. Ions are atoms that have a positive or negative charge. There are five types of ionizing radiation: alpha, beta, gamma, neutron, and x-ray.[3,4] Details of the sources and properties can be found in Table 1. All of these types of radiation can cause clinically significant impacts to a casualty. Clinical effects are determined by isotope, route of exposure, length of time exposed, and strength of and distance from the radiation source.[5]

Exposure to ionizing radiation can occur from natural and artificial sources**. Of greatest concern to healthcare providers is release of ionizing radiation from artificial sources.** These include industrial radiography, diagnostic and therapeutic clinical sources, nefarious

use as part of a radiological exposure device (RED), radiological dispersal device (RDD), or through nuclear weapon detonation. Table 2 discusses potential radiological and nuclear weapons which can be used to expose a population to ionizing radiation.[6,7]

Isotopes are two or more forms of the same element that contain a varying number of neutrons. Commonly used isotopes are divided into four categories of concern:

1. The University Five (C14, P32, I125, I131, and Cf252) are used in laboratories and for medical care.
2. The Industrial Three (Ir192, Cs137, and Co60) are found in industrial radiography sources and are prime for terrorist use due to ease of access and the high energy emitted.
3. The Military Five (H3, U235, U238, Pu239, and Am241) are used in making nuclear weapons.
4. Fission products are radioactive decay products released after a nuclear detonation or power plant accident.

Table 1. Properties and clinical effects of ionizing radiation[8]

Properties and Effects of Ionizing Radiation			
Type	Source	Properties	Clinical Concern
Alpha particles (α)	Charged particles from radioactive decay of heavy nuclei	Travel short distance, shielded by a piece of paper	Greatest risk is posed through internal contamination from ingestion, open wounds, or inhalation.
Beta particles (β)	Electrons from decay of certain radionuclides, including fallout from nuclear detonations	Travel short distance through tissue, most shielded by layer of clothing	Can cause radiation burns, can cause internal exposure
Gamma rays(γ)	Photons from nuclear detonation, or radioactive decay of radionucleotides. Primary hazard of fallout from nuclear detonations. These originate within the nucleus.	High energy and pass through matter easily	Whole body effects from both external and internal exposure if gamma-emitting radionuclides are internalized
X-Rays	Photons from processes originating outside the nucleus, often seen from machines used for industrial or medical usages.	High energy with short wavelength	Same as gamma.
Neutrons	Uncharged particles emitted from fission (i.e. detonation of an improvised nuclear device (IND))	Extremely high energy and can pass through matter easily	Same effects as gamma rays, but causes more damage

Table 2. Radiology and nuclear devices

Radiology and Nuclear Devices				
Device	Description	Dispersal	Effects	Example
Radiation Exposure Device (RED)	radioactive source for the purpose of exposing those nearby to high doses of radiation	Container or sealed source	Radiation effects without trauma	Container hidden on public transportation involving a stolen industrial radiography source
RDD. Also known as a “dirty bomb”	intentionally engineered to disperse radioactive material but without a fission or fusion reaction.	Improvised explosive device	Main concern is blast effects. Radiation exposure to only those close to blast. Radioactive dust and smoke could have some health effects	Explosive mixed with radioactive materials or placement of radioactive material into soil, water, or air

Radiology and Nuclear Devices				
Nuclear Device Detonation	Requires nuclear fission or fusion. Designed to deliver a nuclear detonation at either full or partial yield.	Nuclear blast	High level of external radiation exposure, blast /and thermal injury, and subsequent radiation contamination exposure through fallout	Bomb dropped on Hiroshima or IND

RADIOLOGICAL UNITS

The unit of exposure, the amount of energy deposited in tissue from being irradiated by a source, and the biological effects from being irradiated are described by three different units of measure. Both conventional and SI units of measure are regularly used. The unit of exposure is the Roentgen or Coulomb per kilogram. Deterministic clinical effects from absorbed dose are described in RAD or Gray. Equivalent dose from different types of radiation is described in REM or Sievert.[9,10] Determining equivalent dose applies to stochastic effects and is dependent on type of ionizing radiation.

In the immediate aftermath of an incident, healthcare providers will see radiation exposure measured in Roentgen (R) when using detectors and discussion of Acute Radiation Syndrome (ARS) and Cutaneous Radiation Syndrome (CRS), based on dose received in RAD and Gray. This information is summarized in Table 3. It is extremely important to confirm the unit the detector utilizes, particularly the prefix as milli (m) and micro (μ) are often confused or even omitted when relaying dose and/or dose rate.

Table 3. Units of radiation measurement

Units of Radiation Measurement				
Quantity	Description	Conventional Unit	SI unit	Conversion
Absorbed Dose	Amount of energy deposited per unit mass	Radiation absorbed dose (rad)	Gray (Gy)	100 rad = 1 Gy 1 rad = 1 cGy 1 Gy = 1 J/kg
Dose Equivalent	Measure of biological effects produced from different types of radiation	Roentgen equivalent man (rem)	Sievert (Sv)	100 rem = 1 Sv 1 rem = 1cSv
Some detectors will display in R/hr (roentgen/hour) or mR/hr. For gamma and x-ray exposures in biological tissue, it can be assumed that 1 R ≈ 1 rad ≈ 1 rem.				

CLINICAL INDEX OF SUSPICION

While there are no cases for radiation exposure in the DoDTR – military providers must have a clinical index of suspicion for radiation weapons on the future battlefield. The first step is management is identification and to recognize the risk of radiation weapons and RAD injury in the Area of Operations (AOR). Some patients will present immediately with a burn that was not from a flame or obvious exposure if they were close to the radiation source. The main factors that result in clinical manifestations are time of exposure, distance from source, and any shielding. Other symptoms are relatively non-specific. The severity and onset of symptoms depends on the dose received. The clinical syndromes are described in more detail later in this CPG – but clinicians may be the first to identify the use of radiation weapons based on casualties with the below (non-specific) findings.

Key Symptoms of Acute Radiation Syndrome (ARS) aka 'Radiation Sickness'

1. Prodromal Stage will occur minutes to days after the radiation exposure
   - Nausea and vomiting
   - Diarrhea
   - Fatigue and weakness
   - Anorexia (loss of appetite)
   - Headache

2. Latent Stage will occur hours to weeks after the radiation exposure
   - Temporary improvement or stabilization of symptoms
   - Patients may feel relatively well

3. Manifest Illness Stage occur weeks to months after the radiation exposure
   - **Hematopoietic Syndrome**: Decreased white blood cell count, increased risk of infections, bleeding, and anemia
   - **Gastrointestinal Syndrome**: Severe nausea, vomiting, diarrhea, dehydration, and electrolyte imbalance
   - **Cardiovascular/Central Nervous System Syndrome**: Confusion, dizziness, hypotension, and potentially seizures or coma (at very high doses)
   - **Skin Damage**: Redness, blistering, ulceration, and hair loss

Providers at deployed MTFs should be able to identify these patients if not initially because of the risk/threat of injury than through MTF PI events and clinical case reviews. Given the non-specific nature of these presentations, providers must have an index of suspicion for the clinical manifestations of radiation sickness

DECONTAMINATION CONSIDERATIONS

> *Lifesaving medical care takes priority over radiological decontamination efforts.*
> *Mettler, 2002*

In the case of managing casualties in a known radiation hot zone: t**here is no documented case of medical personnel receiving a clinically significant dose while performing lifesaving interventions on a contaminated casualty**. Medical personnel are extremely unlikely to receive a medically significant acute radiation dose when providing patient care to casualties with radioactive debris in wounds from an RDD (radiologic dispersal device).[4,11] That being said, providers should shield themselves and wear appropriate PPE.

The physical state of the radioisotope will determine the best method of decontamination. If the patient has only been exposed to ionizing radiation, DECON IS NOT REQUIRED.

Personal Protective Equipment (PPE) should be selected such that eyes, nose, mouth, hair, and all exposed skin is covered. Respiratory protection should consist of a N95 or P100 mask. Double gloves and disposable apron or overgarment with long sleeves are sufficient skin coverage for personnel performing decontamination.[5,12] While operating in a tactical or field setting, Mission-Oriented Protective Posture (MOPP) level 4 may be downgraded to mask and gloves in order to provide respiratory and dermal protection (See Appendix A for descriptions of levels of PPE). While full PPE changes may not be feasible when moving from casualty to casualty, frequent glove changes are recommended. During decontamination, the casualty should wear an N95 or P100 mask (or remain in their tactical respirator) to minimize inhalation of any aerosolized radioactive particles. Open wounds should be considered contaminated and irrigated using clean or sterile water and subsequently covered to prevent recontamination. If surgical debridement of radioactive shrapnel is required, consider utilizing x-ray (lead) aprons as PPE for the surgical team, or drape over the patient, when not actively operating. This will reduce any dose received by the providers.

Dry decontamination consists of removing all clothing, equipment, and personal effects from the casualty, and this step alone removes about 90% of external contamination from exposure to radioactive solids or liquids. Further dry decontamination involves brushing the skin to remove loose epithelial cells and/or using lint rollers or masking tape to remove contamination.[6,13] Use of non-ethanol containing baby or wet wipes would be adequate to remove contaminants on skin and should be used in a motion that wipes away from the face and open wounds.

Wet decontamination consists of water and mild soap to remove contamination on the patient's skin. Self-showering for ambulatory patients can be employed for large numbers of casualties. Avoid irritating the skin with aggressive abrasions and avoid contaminated fluid from entering the mouth/nose or wounds. If available, use indoor facilities for wet decontamination in temperatures below 65°F/18°C. If these facilities are unavailable, use of dry decontamination materials is recommended to prevent hypothermia.

Decontamination should be confirmed with appropriate radiological monitoring equipment utilized by personnel familiar with their use (See Appendix B). The goal for decontamination is to reduce external contamination to a level less than two times the background level, however, levels can be over two times without significant health risk to others.

Radiation detectors and dosimeters produce outputs with various different units. When decontaminating a patient, the detector should display in units of counts per minute (cpm) or counts per second (cps). This provides information on the amount of radioactive material present but does not provide information on the energy being deposited in tissue. The recorded cpm before and after decontamination indicate the effectiveness of the method and whether another iteration of decontamination is necessary.

Figure 1. Decontamination principles for radiation and nuclear exposures

Decontamination Principles for Radiation and Nuclear Exposures

- Do not delay lifesaving interventions. TCCC principles take priority.
- Prevent cross-contamination by donning the appropriate PPE (Appendix A).
- Initial survey should include:
  - Confirm radioactive contamination and dose rate if available.
  - Identify isotope if appropriate detector is available. (Appendix B)
  - Evaluate bulk external contamination (granular, powder, sand).
  - Identify radioactive embedded sources (shrapnel) in wounds.
- Goal of prompt wet or dry external decontamination is to decrease the risk of spreading the contamination and causing internal contamination through inhalation, ingestion, or absorption by avoiding the face/wounds.
- Remove all clothing and equipment.
- Cut clothing if needed. Do not rip or tear clothes as this may aerosolize or spread particles. Remove clothing and equipment away from the patient's face and wounds. Consider the use of a barrier device (i.e. mask) to protect patient from inhalation and ingestion of contamination.
- Priority order during the decontamination process:
  - Body orifices
    - When irrigating wounds, protect body orifices and surrounding areas from irrigation run off.
    - Have patient blow nose to remove contamination after obtaining bilateral nasal swabs with moist cotton swab for isotope identification and estimating level of lung radiation (*note swabs collected >1 hour after contamination may not be reliable and swabs may not be feasible in mass casualty events). Nasal and oral washes are not recommended as this can increase risk of ingesting contaminated material. Further information on nasal swabs can be found at https://remm.hhs.gov/nasalswabwarning.htm
  - Open wounds and burns
    - Protect areas adjacent to wound from irrigation run off by wiping gently away from the wound.
    - Use a drape or barrier over wounds during irrigation.
    - Treat burns in accordance with the JTS Burn Care CPG.
    - Radiological contamination may be present in burned tissues.
    - Radioactive particulates identified with detectors should be removed from wounds and followed by wound irrigation.
    - Place particulate matter in shielding containers and remove from patient care area.
  - Intact skin and hair
    - Wipe with baby wipes and/or wash with soap and water.
    - Gently wipe areas from outside-in to prevent spreading.
    - Do not cause abrasions from aggressive rubbing.

Prolonged and aggressive surgical debridement to remove particulate matter is not indicated in a field or deployed setting. The ability to ensure there are no embedded radioactive sources (which is an unlikely event - perhaps only for EOD attempting to render safe an RDD) can provide confidence of limited risk to patient and personnel. The ability to detect dose rate and isotope can provide further data to evaluate health risks.

TRIAGE

In a mass casualty event, assign triage categories based on conventional injury. After stabilizing traumatic injuries, and should resources to estimate dose become available, a secondary triage of casualties must occur to account for radiation. Further details for initial dose estimation (biodosimetry) are available in Appendix C. Those with suspected combined injury are moved to the next higher acuity triage category. If someone is suspected of receiving greater than a 6 Gy dose, they are triaged to expectant until more resources become available.[14] Table 4 provides an overview of how to update triage categories for radiation. More comprehensive triage tools can be found at https://remm.hhs.gov/triagetool5.htm. As the event progresses and additional resources become available, iterative retriage of all casualties across all triage categories to include expectant, must occur.

In isolated irradiation, the most reliable early clinical indicators of whole-body radiation injury are the time-to-emesis and/or elevated body temperature, which can be seen in the early hours following exposure. When at a Role 3, or a Role 2 with lab capability, the most reliable early laboratory indicator is the lymphocyte depletion rate, which may not be available in 24-48 hours depending on the size of mass casualty and degree of infrastructure damage. *While time to emesis is a rapid and inexpensive method for estimating the radiation dose, it should be used with caution because it is imprecise and may lead to very high false positive rate*. [15]

Table 4. Outline of how radiation injury dose modifies mechanical trauma and burns.

Outline of how radiation injury dose modifies mechanical trauma and burns			
Conventional Injury Triage		**Combined Injury Triage**	
Conventional Triage category (trauma/burns without radiation)	Trauma and burns combined with <2Gy (possible vomit >4 hr)	Trauma and burns combined with 2-6 Gy (likely vomit 1-4 hr)	Trauma and burns combined with >6 (highly likely vomit <1 hr)
Immediate (I)	I	I or D variable	E
Delayed (D)	D	D or I variable	E
Minimal (M)	M	D	D or E variable
Expectant (E)	E	E	E
Sources: Adapted from Homeland Security Interagency Policy Planning Guidance for Response to a Nuclear Detonation. Washington, DC, Office of Science and Technology Policy			

TCCC IN A RADIOLOGICAL/NUCLEAR EVENT (MARCHE)^2

Casualty care in a radiological/nuclear event should proceed according to the basic principles outlined in the (MARCHE)^2 sequence as described in JTS CBRN CPG Part I. However, there are some nuances to the application of (MARCHE)^2 in a radiological/nuclear scenario that are outlined in each phase of casualty care in the following sections (highlighted in blue). It is important to note that irradiation or contamination plus trauma, also described as combined injury, adds complexity to casualty care. The (MARCHE)^2 sequence integrates the assessment and response to both trauma and radiologic/nuclear casualties.

CARE UNDER FIRE/EXTREME HOT ZONE

It is important to seek cover at the first indication of a radiological or nuclear event. Even a layer of cloth can protect from large particles, so every attempt should be made to completely cover exposed areas including the eyes and mouth. There are no radiation specific treatments required at point of injury and all efforts should be made towards addressing life-threatening hemorrhage and extricating to a safe area. Medical responders need to understand the importance of minimizing personal exposure time and maximizing distance from a source when responding to casualties. If the tactical situation dictates that some casualty care must occur in the Extreme Hot Zone or Hot Zone, utilization of shielding will lower dose rates, but will increase exposure time. Dragging a casualty a few feet from a source can provide benefit while reducing risk to responders.

In isolated irradiation, the most reliable early clinical indicators of whole-body radiation injury are the time-to-emesis and/or elevated body temperature, which can be seen in the early hours following exposure.

Table 5. Radiological threat in zones of care

Radiological Threat in Zones of Care			
PPE confers no protection against gamma, neutron, and X-ray radiation. Factors that help decrease radiation dose from exposure. ▪ Minimizing time spent near a radiation source. ▪ Maximizing distance from a radiation source. ▪ Increasing the physical shielding.			Recommended PPE. If no PPE available: Flak/Kevlar and any other clothing or gear, you may have on. Sleeves rolled down. If no gas mask, either an N95 mask or cloth to cover orifices.
Care Under Fire Extreme Hot Zone	>10R/h	Exfiltrate immediately, however potential exists for over 10 hours of exposure before receiving 1 Gy	Full face air purifying respirator with a P-100 or HEPA filter. Level C PPE or MOPP 4. Only for radiological environment and other hazards (i.e. chemical) are not present
Hot Zone	>1R/h	Medical assistance Firefighting, Exfiltrate. Over 100 hours of exposure possible before receiving 1Gy	
Tactical Field Care Warm Zone	100mR/h	Intermediate area between Cold Zone and Hot Zone. Over 1000 hours of exposure before receiving 1Gy	Determined by risk level/MOPP 2
Tactical Evacuation Cold Zone	<10mR/h	Initial decontamination of first responder	Standard PPE precautions (gown, gloves, mask)

These dose rates were modified from the 3rd edition of the FEMA planning guidance for IND response. Commanders can adjust dose rates based on mission requirements.

Table 6. Point of Injury (Extreme Hot Zone / Hot Zone Response - (MAR)[2]

Point of Injury (Extreme Hot Zone / Hot Zone Response - (MAR)[2]	
TCCC	**CBRN**
Massive Hemorrhage	**Mask**
Stop life-threatening external hemorrhage if tactically feasible: ▪ Direct casualty to control hemorrhage by self-aid if able. ▪ Use a CoTCCC-recommended limb tourniquet for hemorrhage that is anatomically amenable to tourniquet use. ▪ Apply the limb tourniquet over the uniform clearly proximal to the bleeding site(s). If the site of the life-threatening bleeding is not readily apparent, place the tourniquet "high and tight" (as proximal as possible) on the injured limb and move the casualty to cover.	▪ Don mask ▪ Help casualty don mask or ensure proper seal if mask already in place. ▪ If using powered air purifying respirator or self-contained breathing apparatus, ensure it is functional. ▪ A surgical mask or layer of cloth can provide protection and prevent inhalation or ingestion of large radiological particles if higher levels of respiratory PPE are not available
Airway	**Antidotes**
Airway management is generally best deferred	No antidotes are indicated in the Hot Zone for radiological/nuclear events
Respiration	**Rapid Spot Decontamination**
▪ Assess: normal, shallow, labored, absent? ▪ Complete the CRESS assessment and determine if caused by life threatening trauma. ▪ Respiratory intervention is generally best deferred	At the point of injury, physical removal of the radioactive shrapnel/rapid spot decontamination is indicated if it can be done quickly- otherwise defer. (Rapid spot decontamination for radiological materials involves brushing or wiping off particulate matter. Reactive skin decontamination lotion is not indicated for radiological contamination.) If a fragment is identified in an extremity, use an available instrument to immediately remove it and discard as far away as possible> Limit attempts at removal to <10 seconds. A tourniquet should be placed above the wound in case removal results in massive hemorrhage. If the fragment can't be removed, consider shielding. (Shielding discussed in evacuation considerations)
Extraction	
Egress away from the threat	

Source: JTS. Chemical, Biological, Radiological and Nuclear (CBRN) Injury Part I: Initial Response to CBRN Agents CPG.

TACTICAL FIELD CARE / WARM ZONE

Care in this phase should be rendered with consideration to "as low as reasonably achievable" principles in order to minimize further exposure or contamination once extracted from the Hot Zone. Moving to the basement of a building would be an ideal example. Ensure that medical equipment and supplies are covered. Ideally all but immediate life-saving interventions would be deferred until the patient reaches the Cold Zone where risk of further contamination is minimal. In the event that the radiation field is so large, or evacuation movement is restricted, these considerations may necessitate the transition to prolonged field care while still in the Warm Zone.

TRIAGE IN MASS CASUALTY

Immediate
- Life threatening
- Combined injuries
- Internal contamination

Delayed
- Evidence of radiation inquiries (2-10 gray)
- Emesis < 4 hours
- Lymphocytes drop > 50% w/in first 48 hours

Minimal
- Radiation exposure with no evidence of injury
- Worried well

Expectant
High does (>20gy)

Initial Evaluation

- Assess for COMBINED injuries causing immediate loss of life (e.g. exsanguination)
- Decontaminate AFTER stabilization
- Traumatic injuries are more acutely life threatening than radiation injuries
- Removal of clothing and washing of patient >90% effective
- Requirement for some medical providers to work in a 'radiation environment'
- Risk to providers is very low
  Don't delay resuscitation for decon

Table 7. Assessment at the Dirty CCP (Warm Zone)– (M A R C H E)[2]

Assessment at the Dirty CCP (Warm Zone)– (M A R C H E)[2] Treat life-threats ONLY	
TCCC	**CBRN**
Reassess: Are immediate life threats addressed? Treatment of trauma and burns takes priority over radiological decontamination and treatment.	
M.A.R. Reassessment (Massive hemorrhage, Airway, Respirations) ▪ Stop all external hemorrhage. ▪ Advanced airway as indicated. ▪ Treat tension pneumothorax. ▪ Ventilator support (positive end expiratory pressure support, pressure monitoring)	M.A.R. Reassessment (Mask, Antidote, Rapid spot decontamination) ▪ Apply or seal mask to prevent inhalation or ingestion of particles (level C if available, if not surgical mask) ▪ Reassess CRESS (Consciousness, Respirations, Eyes, Secretions and Skin). ▪ Reassess need for rapid spot decontamination. ▪ Use detectors if available.
Circulation	**Countermeasures**
▪ Pulse check ▪ Skin check ▪ Assess for shock. ▪ Fluid resuscitation per TCCC guidelines only if absent radial pulse ▪ IV/IO access if needed immediately	▪ Treat life-threats ONLY. ▪ Rinse wounds with sterile saline or clean water, wash externally with soap and water until the patient registers a reading < 2 times background (if detectors are available). ▪ Anti-emetics after time of onset of vomiting is documented. ▪ Other countermeasures rarely indicated in Warm Zone except in prolonged field care scenario. (See countermeasures discussion.)
Hyperthermia	
▪ Package the casualty. ▪ Protect from lethal triad: Hypothermia, Acidosis, and Coagulopathy.	
Head Wounds (Altered Mental Status)	
Determine whether casualty's altered mental status is due to shock or trauma.	
Evacuation	
▪ Determine Evacuation Priority. Note that surgical intervention on a radiation casualty should occur within 48 hours of injury before depression of cell lines occur. ▪ Fill out Casualty Card. ▪ Document time of exposure if known.	

Assessment at the Dirty CCP (Warm Zone)– (M A R C H E)[2] Treat life-threats ONLY
▪ Document onset of vomiting (for dose estimates). ▪ Move casualties for further decontamination or to evacuation platform. ▪ May need to use shielding (shelter). ▪ The Dirty CCP may be far from the point of injury, necessitating exhausting casualty carries and exposing rescuers to heat injury from the burdens of PPE.
***Time is a major component of biodosimetry estimates. Careful documentation of exposure time and time to onset of symptoms is important for subsequent medical decision-making. Also, there is a need to continually reassess symptoms for triage purposes to be put into context of operational capabilities.

Source: JTS Chemical, Biological, Radiological and Nuclear (CBRN) Injury Part I: Initial Response to CBRN Agents Clinical Practice Guideline.

TACTICAL EVACUATION CARE

Triage principles in this CPG should be heavily emphasized to support efficient use of CASEVAC and MEDEVAC resources. Role 1 to Role 3 evacuation priority should be based on trauma in combined injury casualties. ***Retriage for evacuation priority is crucial***. If a casualty starts exhibiting signs and symptoms of significant exposure, the provider may need to change the triage category depending on evacuation capability, time to surgery and other "non-clinical" risk assessments by the triage person in charge. Evacuation out of theater for those with exposures likely to cause Acute Radiation Syndrome are described below. Additional guidance on evacuation operations in contaminated environments can be found in JP3-11. The decision to use ground and air transport platforms to transport contaminated casualties lies with Commanders after calculating acceptable risk, informed by medical personnel with expertise in this area. Risks include but are not limited to:

- contaminated casualty or retained radioactive material.
- cumulative exposure to transport and medical crew while transiting the contaminated environment.
- cross contamination of the transportation platform.

Although aircraft can safely fly through fallout (ATP 3-05.11) and the risk of ingestion and inhalation is small with PPE, rotor wash from helicopters can disrupt/spread settling radiological dust particles, liquids, and solids and can increase risk. Ground personnel and aircraft crews conducting CASEVAC/MEDEVAC operations should use PPE guidelines in this CPG if the aircraft is picking up patients in a Warm Zone. The use of protective masks (military or Level C) may provide some protection initially, but the canister or filters of the masks can accumulate radiological particles during prolonged use.

When preparing to execute a CASEVAC/MEDEVAC for a radiation casualty, medical providers should account for ensuring decontamination, isolating immunocompromised patients, and access to an appropriate receiving medical facility. Those who still have embedded shrapnel may require shielding. Portable shielding devices such as lead rolls are not currently issued as common equipment and unlikely to be necessary. Not all patients require shielding, only patients with retained radioactive material which is highly unlikely. The shielding device only needs to be large enough to cover the radioactive hazard, not the whole patient.

PROLONGED FIELD CARE / ROLE I-3 - CARE / COLD ZONE

Patient management during this phase should address both contamination and exposure. Patients with internal contamination require specific countermeasures based on the relevant radionuclide as discussed below and referenced in Table 10. Patients with exposure require a dose estimate (see Appendix C for details on biodosimetry) to determine appropriate level of monitoring and treatment. Developing dose estimates or using qualitative factors to categorize patients according to risk is a necessary secondary triage to appropriately determine disposition and allocate resources.

Clinical impacts are divided into deterministic and stochastic effects. Deterministic effects are dose dependent and consist of the ARS sub-syndromes and CRS. ARS and CRS are discussed below. Stochastic effects are probability driven and are most focused on long-term cancer risk.

ACUTE RADIATION SYNDROME

Acute Radiation Syndrome is a combination of clinical signs and symptoms occurring in stages over a period of hours to weeks due to a significant partial-body (70%) or **whole-body exposure of > 1 Gy** (100cGy of ionizing radiation), as injury to various tissues and organs is expressed. ARS is caused by >1 Gy / 100 rad whole-body doses of ionizing radiation. ARS follows a predictable clinical course through four phases: 1) prodromal, 2) latent, 3) manifest illness, 4) recovery or death. The transition time between phases depends

on the dose of radiation absorbed. The higher the whole-body dose, the shorter each of the phases. Table 8 below depicts time to onset of prodromal symptoms based on dose.[16]

Figure 2. Time to Emesis

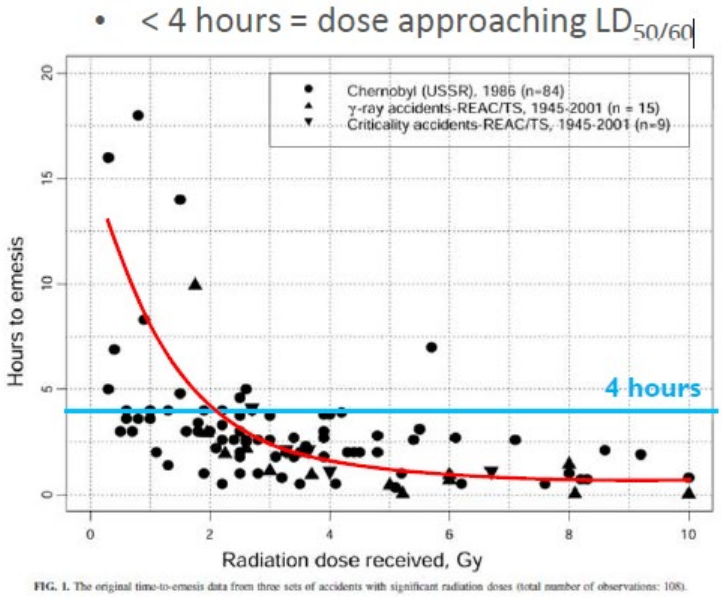


FIG. 1. The original time-to-emesis data from three sets of accidents with significant radiation doses (total number of observations: 108).

Nausea, vomiting, diarrhea, fever, and transient skin erythema characterize the prodromal phase, which may last minutes to days. The patient may then appear well for a few hours, or even a few weeks during the latent phase, which is characterized by silent cell and tissue destruction. This destruction is later manifested clinically as one or more of three syndromes: 1) hematopoietic (H-ARS), 2) gastrointestinal (GI-ARS), 3) neurologic (N-ARS). Death can occur within days for gastrointestinal and neurologic but may not occur for weeks for hematopoietic.[14,17-18]

Without treatment, the LD50/60 for ionizing radiation is about 4 Gy. With appropriate intervention and treatment, the dose goes up to about 6 Gy. Experience from those who receive even higher doses suggest that with aggressive resuscitation and critical care, survival can be extended by months. This factor can lead to the eventual need to evacuate these casualties.[14]

Table 8. Acute Radiation Syndromes

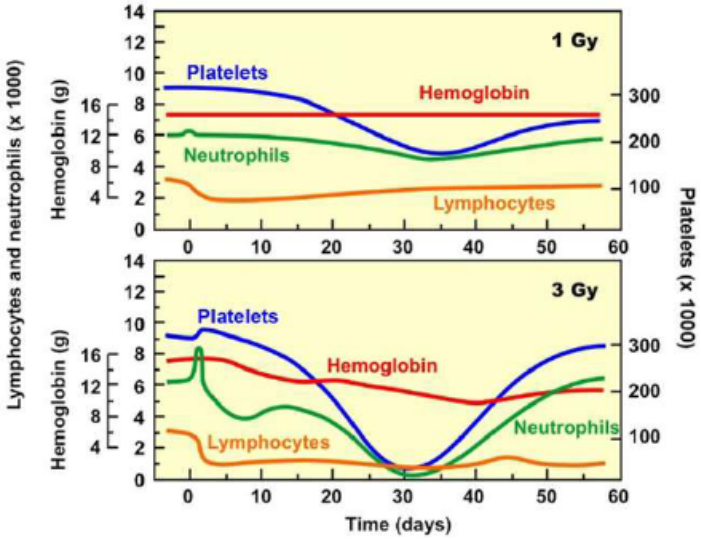
Acute Radiation Syndromes									
	Gastrointestinal		**Hematologic**		**Neurologic**		**Treatment**	**Prognosis**	
Dose	Vomiting (time to, and %)	Diarrhea	Lympho-cytopenia	Body Temp	Headache	Consciousness	Clinical Care	Manifest onset	Mortality
<1Gy	Rare	None	None	Normal	None	Normal	None	>30d	None
1-2Gy	>2h, 10-50%	None	48h-Mild-moderate	Normal	Mild	Normal	Outpatient Observation	>30d	None likely
2-4Gy	1-2h, 70-90%	Mild	48h-Moderate to severe	↑ in 1-3h	Mild	Normal	Hospital observation	18-28d	Rare at 2Gy, ~50
4-6Gy	<1h, 100%	Mild within 3-8h	48h-severe	↑ in 1-2h	Moderate, 2-24h	Normal	Hospital	8-18d	20-70% at 4-8w
6-8Gy	<30min, 100%	Heavy within 1-3 h	24h-severe	↑ <1h	Severe, 3-4h	May be altered	Hospital	<7d	> 70% at 1-2w
>8Gy	<10min, 100%	Heavy <10min	<24h-severe	↑ <1h	Severe, 1-2h	Lost in sec-min	Palliative	Immediate	Likely within 1-2w

Source: Created by COL (Ret.) Melissa Givens, USA

Sequelae in doses less than 1 to 2 Gy can take more than two weeks to manifest. In a mass casualty producing event, those with mild doses of 1-2Gy without trauma, could be observed as outpatients and evacuated using non-medical platforms. These casualties should be continually observed and regularly re-evaluated for deteriorating health status. Casualties exposed to moderate to severe doses (>2Gy) should be hospitalized and prioritized for evacuation to reach specialty care prior to onset of manifest illness. Supportive care is the mainstay of treatment for patients in the prodromal phase of ARS and can be managed at Roles 1-3, or in a prolonged field care setting, while pending evacuation.

Therapy which may be necessary pending movement to definitive care is outlined In Table 9. Consider early consultation with hematology/oncology and/or the advisor line for symptom management/treatment of acute radiation syndrome.

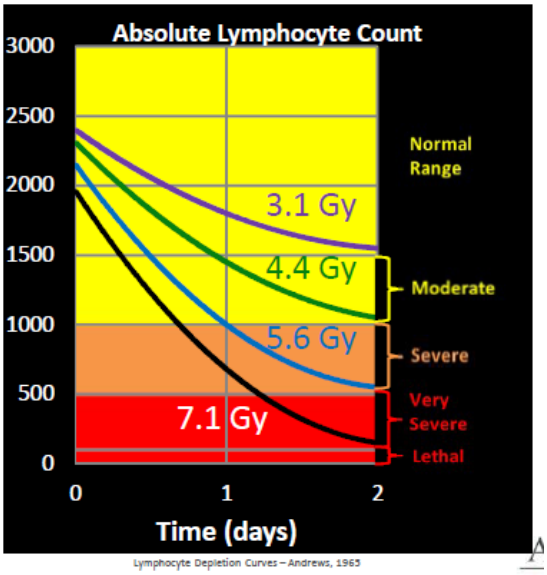
Figure 3. Radiation effect on complete blood



- Lymphocytes are highly radiosensitive
- Lymphocyte count can be used for early diagnosis of ARS
- 50% reduction of lymphocytes at 48hr for dose >/+3 Gy

Source: The Medical Effects of Ionizing Radiation (MEIR) Course

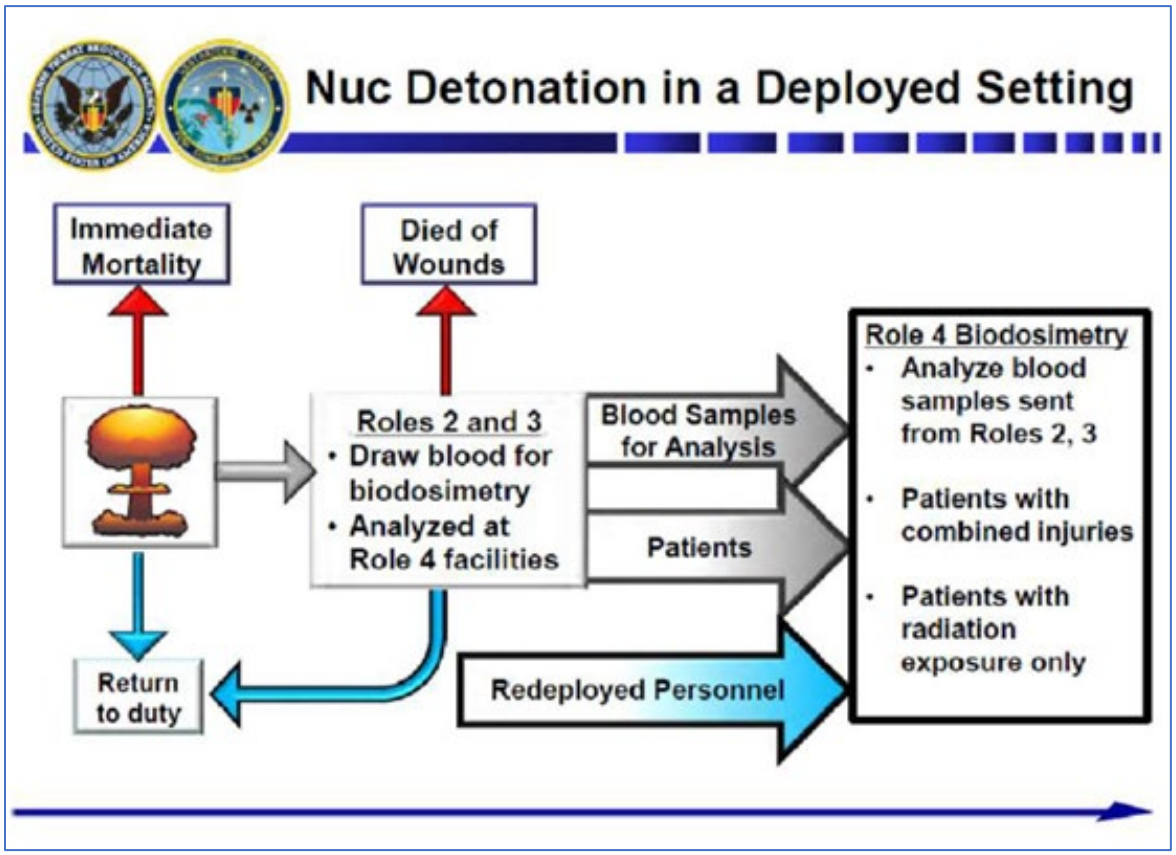
Figure 4. Dose estimates using blood lymphocyte kinetics



- Lymphocyte response is dose dependent – Large depletion indicates larger doses.
- Can be used to estimate doses between 3-7 Gy – Qualitative response otherwise
- Drops greater than 50% in 48 hours indicate poor programs (> 4Gy).

Source: Lymphocyte Depletion Curves – Andrews, 1965 The Medical Effects of Ionizing Radiation (MEIR) Course

Figure 5. Nuclear detonation in a deployed setting



Source: The Medical Effects of Ionizing Radiation (MEIR) Course

Table 9. Acute radiation syndrome therapy

Acute Radiation Syndrome Therapy		
Indication	**Intervention**	**Considerations**
Nausea/Vomiting	Ondansetron: IV: 0.15mg/kg or 8 mg followed by 1 mg/h for the next 24 hours PO: 8 mg ODT/PO q 4h	Ensure vomiting time of onset is documented prior to giving antiemetics
Vomiting/diarrhea fluid replacement	Crystalloid and enteral resuscitation as tolerated	Burns must be taken into consideration for volume replacement
Infection prophylaxis Indicated if ANC <1000 µl	▪ Reverse isolation and neutropenic precautions ▪ Gut decontamination with antibiotics ▪ Maintain enteral nutrition. ▪ Use povidone-iodine or chlorhexidine for skin disinfection or mild soap and water. ▪ Encourage good oral hygiene.[19,20]	Avoid antacids and H2 blockers because of risk of bacterial overgrowth.
Infection	Antibiotics (i.e. fluoroquinolone), antiviral (i.e. acyclovir), and antifungal (i.e. fluconazole) therapy should be used to treat infections. [19,20]	May be considered as prophylaxis in those with persistently low absolute neutrophil count (ANC). Reference the Infectious Diseases Society of America (IDSA) neutropenic fever guidelines.

Acute Radiation Syndrome Therapy		
Cytopenia	Blood component products (Irradiated and leukocyte depleted)	Time to cell line depletion is dose dependent
Prophylaxis for exposure >2G Or H-ARS	▪ Filgrastim: 10 mcg/kg/day (rounded to nearest vial size 300mcg/0.5ml or 480mcg/0.8ml) subcutaneous. Continue daily administration until ANC > 1000 for 3 daily CBC or exceeds 10,000 after radiation induced nadir OR ▪ Pegfilgrastim: 6mg/0.6ml subcutaneous. Second dose one week after initial dose OR ▪ Sargramostim: 7 mcg/kg subcutaneous for adults and pediatric patients AND ▪ Romiplostim: 10 mcg/kg subcutaneous as a single dose. [19-23]	▪ Administer as soon as possible after suspected or confirmed exposure dose > 2 Gy, do not delay if CBC not available. ▪ Administration within 24 hours has been associated with increased survival in animal studies. There is likely benefit when given past 24 hours

COMBINED INJURY

Nuclear weapons and RDD detonations can result in radiation exposure, external and internal contamination, and concomitant trauma. Combined injuries have a synergistic effect leading to a poorer prognosis.[24,25]

Patients with hematopoietic subsyndrome of ARS will have an increased risk of infection and hemorrhage. Myeloid cytokine therapy and romiplostim should be initiated as soon as possible.[24,26,27] Surgical procedures should be completed as soon as possible before lymphopenia and thrombocytopenia occurs. Use of cytokines may prolong the surgical window prior to cell line depletion. Transfusions should be accomplished with irradiated blood products, when possible.

Table 10. Combined Effects of Whole-Body Irradiation and Burns in Various Animal Models

Combined Effects of Whole-Body Irradiation and Burns in Various Animal Models		
Model	Injury	Lethality
DOG	20% Burn	12%
	100 cGy	0
	Combined	73%
PIG	10-15% Burn	0
	400 cGy	20%
	Combined	90%
RAT	31-35% Burn	50%
	250 cGy	0
	Combined	95%
GUINEA PIG	1.5% Burn	9%
	250 cGy	11%
	Combined	38%

Source: The Medical Effects of Ionizing Radiation (MEIR) Course

- Increased risk of mortality
- Prognosis is worse
- Mortality multiplier
- Synergistic effect

INITIAL MEDICAL CARE

- Standard life saving interventions for combined injuries.
- XABCs (Exsanguination risks, Airway, Breathing, Circulation).
- Assess risks for Acute Radiation Syndrome AFTER lifesaving treatment.
- Vomiting <4 hours → Presume patient **WILL be** affected.
- Begin serial Complete Blood Counts every 6-8 hours to assess for hematopoietic subsyndrome on all patients at risk.
- Lymphocyte kinetics: 50% drop in lymphocytes at 48 hours correlates with 3-4 GRAY dose.
- Consider advanced biodosimetry techniques like Dicentric Chromosome Assays (DCA).

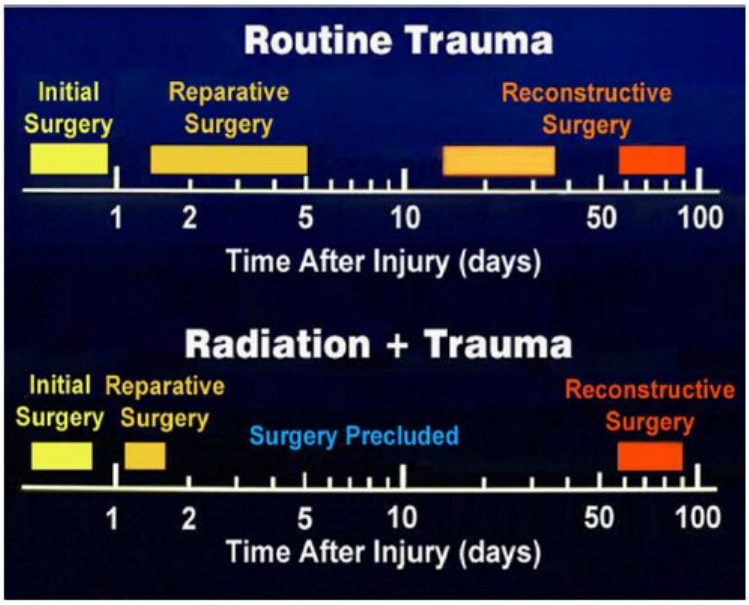
PREGNANCY

- Fetus is very sensitive to radiation.
- Dose to fetus is usually less than mother, except when:
  - Internal contamination is present - bladder proximity to uterus
  - With radioiodine exposure - the fetal thyroid is very iodine avid after 12 weeks
- Requires patient specific dose estimate.
- Category C drugs (adverse effect in animals but not studied in humans)
- All colony stimulating factors
- Most antimicrobials
- Many antiemetics
- Water is a great way to shield from radiation.

EARLY SURGICAL INTERVENTION

- Refers to procedures that are not lifesaving (which should be done immediately), but procedures that should be done within 1-2 weeks for a normal non-irradiated patient (e.g. facial bone fractures)
- **Surgery should be done before Neutrophils and Platelets begin dropping**
- Within the first 36 – 48 hours
- Use of G-CSF cytokines might be able to extend this window

Figure 6. Surgical timing within 36-48 hours



Source: The Medical Effects of Ionizing Radiation (MEIR) Course

INTERNAL CONTAMINATION

Internal contamination is the result of ingestion, inhalation, or contamination of open wounds with radioactive material. Treat these patients like an occult toxic exposure with a full toxicology work up. Isotope identification, as ascertained by exposure history or use of detection equipment, is crucial in the determination of medical management. Some general principles apply to the care of these patients based on reducing ongoing exposure and incorporation. Available methods of reducing internal contamination include blocking, dilution, chelation, and altering the chemistry to enhance elimination of the isotope from the body. Lavage or cathartics can reduce absorption in the GI tract; pulmonary load can be reduced by bronchoalveolar lavage; and contamination in wounds can be excised or washed. Direct further treatment at decorporation of the isotope.

There are a limited number of countermeasures which are approved for use in cases involving radioactive cesium, strontium, iodine, and plutonium. Medical intelligence, modeling, and use of radionuclide detectors will help create a comprehensive picture for diagnosis and treatment of internal contamination. Management of internal contamination should occur as described in Table 10 within 24 hours post-event and if outside the initial 24-hour window pursue treatment based upon expert guidance and recommendation. Potassium iodide is of limited utility outside of nuclear power accidents and in pregnant/breastfeeding women and children. Treatment for some of the more common isotopes is listed in Table 11.

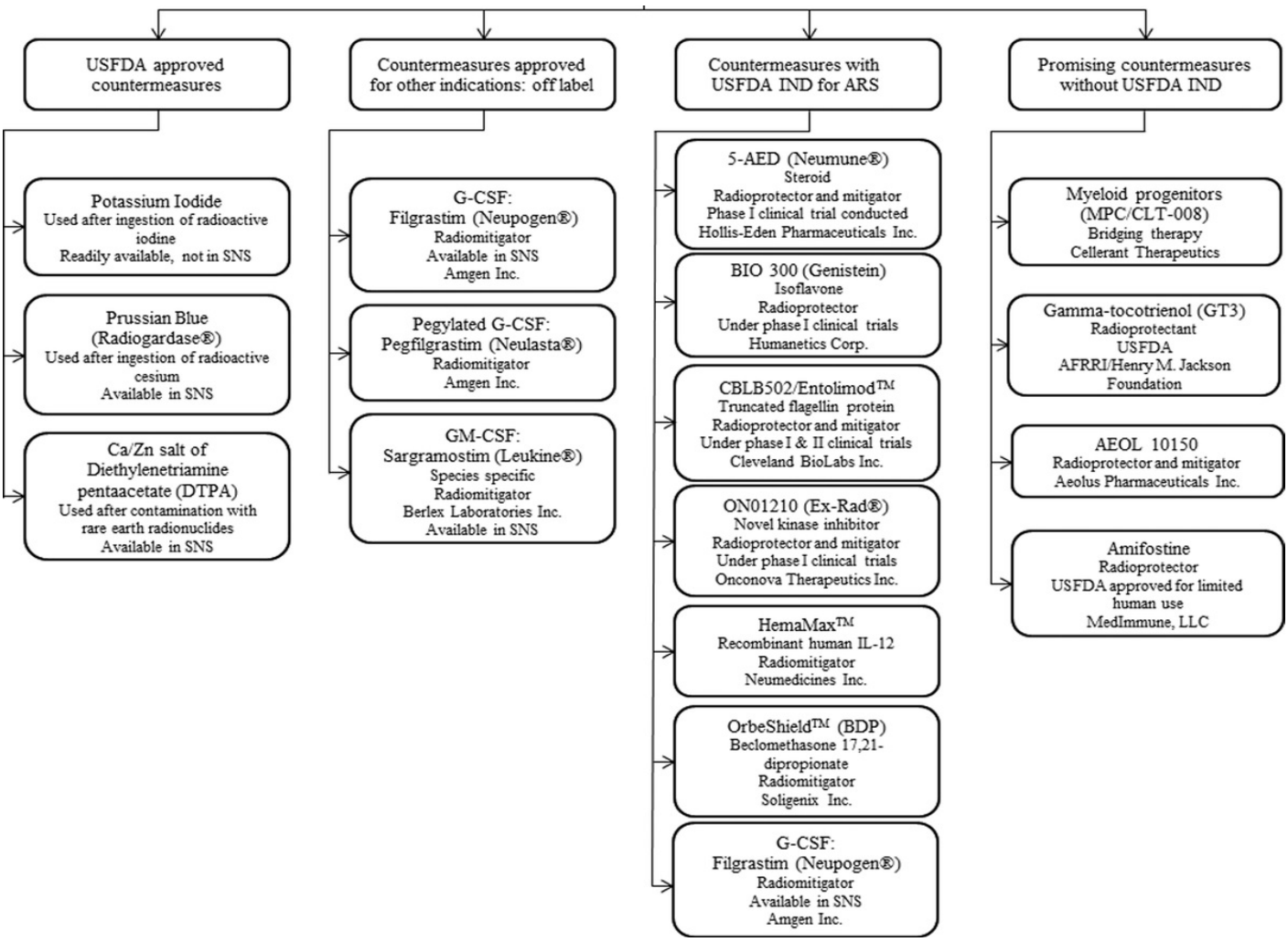
RADIOIODINE PROTECTION

- Use of KI for protection of the thyroid
- Administer early
- Ideally before exposure within 24 hours
- Preferably within 4 hours post exposure
- Protection lasts 24 hours
- Dose daily as long as there is a risk
- Prioritize sheltering in place for those intolerant of KI, pregnant and lactating females (FDA.gov)

Table 11. Treatment options for selected radionuclides [28]

Treatment Options for Selected Radionuclides		
Radionuclides of:	**Treatment**	**Dose**
Plutonium Americium Curium	Ca-DTPA or Zn-DTPA Ca-DTPA is shown to be 10 times more effective than Zn-DTPA if given <24 hours post-exposure.[27,28]	1.0 gram once a day 5ml slow IVP or dilute in 250ml D5, LR, or NS and infuse over 30 min If only inhalation, then nebulize as 1:1 solution Switch to Zn-DTPA for maintenance
Uranium	Sodium bicarbonate	Dose to urine pH of 8-9 Start with 1-2mEq/kg IV (slow infusion)
Cesium	Prussian blue	3.0 grams three times a day (orally)
Strontium	Calcium phosphate or aluminum hydroxide[27]	Calcium phosphate/ Aluminum hydroxide 1200 mg orally within 24 hours or prior to intake
Radioiodine	Potassium iodide. Delay in treatment greater than 4 hours results in greater uptake of radioactive iodine in the thyroid	For casualties 18 to 40 years old, 130mg orally. For casualties over 40 years, KI only indicated for exposures >5Gy

Figure 7. Current USFDA Radiation Countermeasures and Under Development



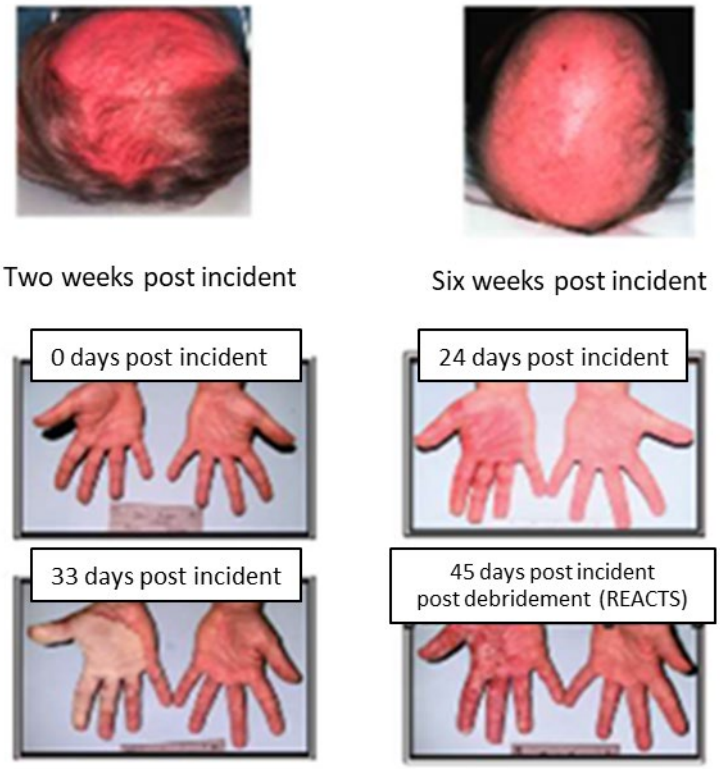
Source: Singh VK; Romaine PLP, Seed TM. Medical countermeasures for radiation exposure and related injuries: characterization of Medicines, FDA-approval status and inclusion into the strategic national stockpile. Health Physics 108(6):p 607-630, June 2015:

CUTANEOUS RADIATION INJURY

Cutaneous radiation injury (CRI) is also known as local radiation injury and is the sequela of skin exposure to large doses of radiation. The threshold dose to cause CRI is highly variable due to both patient factors and the properties of the radiation (dose, dose rate, and radiation quality). CRI can occur in the absence of ARS. When it occurs with ARS, it is known as CRS. The extent of cutaneous injury is an important determinant of survival. Immediate erythema typically indicates a thermal or chemical burn. Erythema that occurs within 2 hours of gamma exposure indicates very high local exposure. Most skin changes will occur more than one week after exposure.[29,30] If acute radiation skin exposure is suspected, cool water may decrease inflammation. Conservative treatments adapted from non-radiation skin injury such as topical steroids, antihistamines, and antibiotics may be useful.[20,31] Systemic antibiotic therapy is not recommended. Pain control and fluid replacement is an important part of therapy. One can expect lower fluid requirements than with thermal burns, but fluid therapy should be tailored to the clinical condition of the patient.[30]

Advanced skin care in the form of skin grafts or even amputation to control necrotic tissue may be necessary in those with severe exposure.[30,31] Other therapies (likely only available at higher echelons of care), such as pentoxifylline, α-tocopherol, transforming growth factor-β, fibroblast growth factor, interferon-γ, and estradiol may be considered in consultation with radiation and burn or skin care specialists.[32-35]

Figure 8. Timeline of CRI



- 3 Gy: Epilation typically begins 2-4 weeks post incident
- 6 Gy: Erythema may occur within hours post incident then disappear with secondary erythema appearing 2-4 weeks post-incident
- 10-15 Gy: Dry desquamation appears 2-4 weeks post incident
- 15-25 Gy: Moist desquamation is seen 2-4 weeks post incident

Figure 9. Cutaneous injury from fluoroscopy

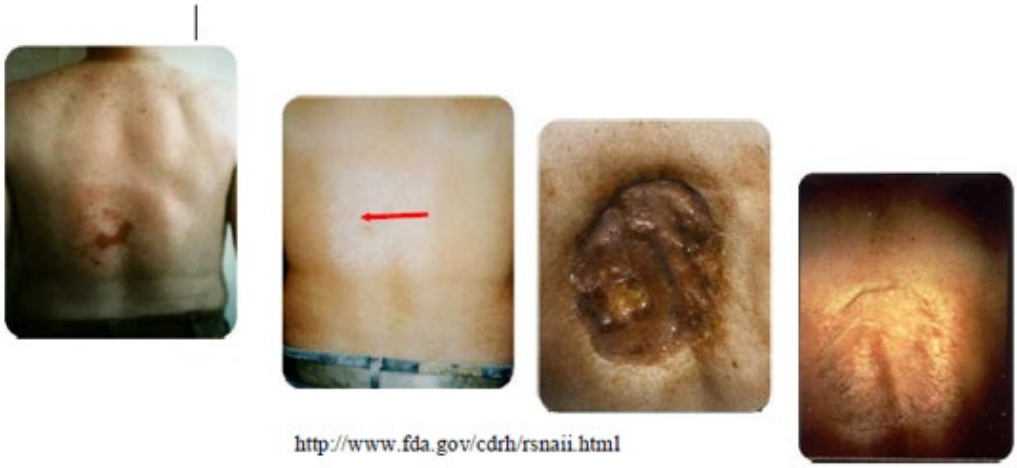


Table 12. Cutaneous Radiation Injury Therapies (CRI) Therapies [37-39]

<table>
<tr><th colspan="3">Cutaneous Radiation Injury Therapies</th></tr>
<tr><td colspan="3">Granulocyte-Colony Stimulating Factor (G-CSF) and Granulocyte Macrophage- Colony Stimulating Factor (GM-CSF) induce proliferation and differentiation of hematopoietic stem cells. The FDA has approved filgrastim (G-CSF), Pegfilgrastim (pegylated G-CSF), and sargramostim (GM-CSF)to treat the hematopoietic subsyndrome of ARS due to radiologic or nuclear incidents.[25] Pegfilgrastim is the pegylated form of filgrastim that has delayed elimination and thus only needs to be dosed every 1-2 weeks. This variable property would allow for one time battlefield dosing until a casualty can be evacuated to definitive care. Romisplostim can be combined with G-CSF or GM-CSF to stimulate proliferation of bone marrow megakaryocytes and associated platelet response and is FDA approved for exposures >2Gy.</td></tr>
<tr><td colspan="3">Decision to administer:
▪ Administer as soon as possible after suspected or confirmed exposure dose > 2 Gy, do not delay if CBC is not available.
▪ Administration within 24 hours has been associated with increased survival in animal studies. There is likely benefit when given past 24 hours.</td></tr>
<tr><td>Filgrastim</td><td>10 mcg/kg/day (rounded to nearest vial size 300mcg/0.5ml or 480mcg/0.8ml) subcutaneous</td><td rowspan="2">G-CSF, pegylated G-CSF are available as single dose vials or single dose prefilled syringes intended for subcutaneous injection. Both products require refrigeration (2C-8C) for storage. The manufacturer of prefilled filgrastim syringes states the product can be used for up to 24 hours when removed from refrigeration and the manufacturer for Pegfilgrastim states the product can be used for up to 48 hours when removed from refrigeration</td></tr>
<tr><td>Pegfilgrastim</td><td>6mg/0.6ml subcutaneous
Second dose one week after initial dose</td></tr>
<tr><td>Sargramostim</td><td>7 mcg/kg subcutaneous for adults</td><td>Sargramostim</td></tr>
<tr><td>Romiplostim</td><td>10 mcg/kg subcutaneous as a single dose</td><td>Romiplostim</td></tr>
<tr><td colspan="3">Complications and side effects:
▪ Bone pain and headache are the most common.
▪ Rash, drug fever, GI symptoms, thromboembolic events, pulmonary syndrome (dyspnea and hypoxia)
▪ Rarely splenic enlargement leading to rupture, caution with sickle cell disease</td></tr>
</table>

PERFORMANCE IMPROVEMENT MONITORING

POPULATION OF INTEREST

1. All patients with exposure to radiation
2. All patients with exposure to radiation and concomitant trauma injuries (Severe ISS >16 and >2 body regions with AIS >= 2, SBP <100, HR > 100 within 3 hours of injury
3. All patients with exposure have dosing estimates documented, either from direct dosimetry or clinical criteria.

INTENT

1. Biodosimetry estimated on all patients using exposure time, time to vomiting, +/- ANC.
2. Radionuclides are identified as early as possible, and countermeasures enacted according to Table 10
3. Complete blood counts are performed as early as possible and repeated every 8 hours for patients with >1Gy exposure.
4. Patients with >1Gy exposure requiring surgery receive surgery as soon as possible.
5. Patients with >2Gy exposure receive countermeasures according to Table 11.
6. Patients with ANC<1000 receive gut decontamination. 7.Patients with >1Gy requiring blood products receive irradiated leukocyte-reduced blood.

PERFORMANCE/ADHERENCE METRICS

- Number and % of patients with exposure who have documented exposure estimates.
- Number and percentage of patients with combined injuries (exposure plus trauma/burn).
- If burn present – document %TBSA
- Document **time of exposure** and **exposure time** (duration of exposure)
- Document PPE
- Document source and type of radiation if known
- Document time to emesis
- Document temperature Q1 hour for first 4 hours and then Q2 hours for first 24 hours

DATA SOURCES

- Patient record
- DoD Trauma Registry
- TMDS

SYSTEM REPORTING & FREQUENCY

The above constitutes the minimum criteria for PI monitoring of this CPG. System reporting will be performed annually; additional PI monitoring and system reporting may be performed as needed.

The JTS Chief and the JTS PI team will perform the systems review and data analysis.

RESPONSIBILITIES

The trauma team leader is responsible for ensuring familiarity, appropriate compliance, and performance improvement monitoring at the local level with this CPG.

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36. Neupogen (filgrastim) Healthcare Provider Site by Amgen.
37. Nuelasta (pegfilgrastim) Official Patient Website.
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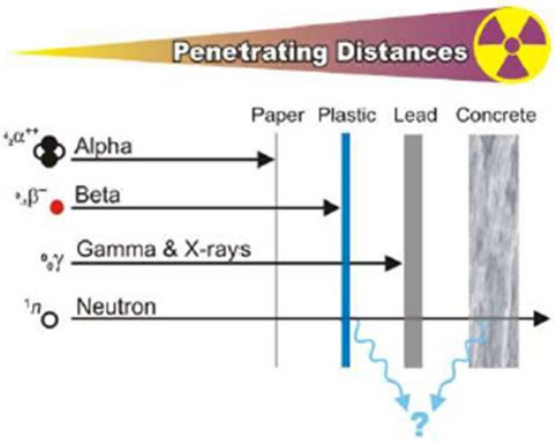
APPENDIX A: PERSONAL PROTECTIVE EQUIPMENT

Level of risk to responding personnel is based on potential exposure to ionizing radiation and contamination. While PPE easily confers protection from alpha and beta particles, PPE cannot protect against external exposure from high energy and highly penetrating types of ionizing radiation such as gamma rays(see Figure 1). PPE considerations can include a broad spectrum of civilian, military, government, and field expedient options that may or may not be available during an initial response. Table 1 describes PPE levels and Table 2 provides recommended levels of PPE in a radiation emergency. Further details on both Military PPE, or Mission Oriented Protective Posture (MOPP) gear and Civilian PPE are described in Tables 3 and 4.

Figure 1. Types of Ionizing Radiation



Source: The Medical Effects of Ionizing Radiation (MEIR) Course

Table 1. Levels of PPE

	Level A	Level B	Level C	JSLIST
				
Air supply	Self-containing breathing apparatus or supplied air respirator; commercial NIOSH CBRN approved.	Self-containing breathing apparatus or supplied air respirator; commercial NIOSH CBRN approved.	Tight-fitting full-face piece air purifying respirator with P-100 filter; organic vapor and acid gas cartridges/ canister	M-40 or M-50 mask with air purifying cartridges/ canister
Suit	Fully encapsulating chemical resistant suit and duct tape to seal seams	Non-gas light encapsulating suit	Tyvek or equivalent garments and duct tape to seal seams	MOPP 4 JSLIST
Gloves/ Boots	Chemical resistant over gloves and boot covers	Chemical resistant over gloves and boot covers	Double gloves and boot covers	Double gloves and over boots
Situations for use	Environments that are immediately dangerous to life and health; working with substances that can be absorbed by or are hazardous to skin	Environments that immediately dangerous to life and health; only if substances cannot be absorbed by or are not hazardous to skin	Final response, search and rescue, and decontamination	First response, search and rescue and decontamination

Table 2. PPE in a radiation emergency

First Responder: Recommended PPE and Practices in a Radiation Emergency	
Emergency Type	**Recommended PPE**
Radiation plus chemical and/or biological hazard: "combined hazard" event	▪ Before combined hazard(s) are well characterized: first responders should be instructed to wear PPE ensembles that protect against anticipated (potentially multiple) hazards. ▪ After combined hazards are confirmed: first responders should be instructed to wear PPE ensembles that product against identified hazards.
Radiation only event with high risk of contamination (and non-radiation hazards have been excluded): e.g., radiological dispersal device)	Level C usually provides sufficient respiratory and dermal protections.
Radiation only event with high risk of exposure (and non-radiation hazards have been excluded): e g., radiological exposure device	▪ PPE confers no protection against high energy highly penetrating forms of ionizing radiation. ▪ Factors that help decrease radiation dose from exposure. ▫ Minimizing time spent near a radiation source. ▫ Maximizing distance from a radiation source. ▫ Increasing physical shielding between a person and a radiation source.

Source: Radiation Emergency Medical Management (hhs.gov)

Table 3. Military PPE – MOPP Gear

MOPP Gear	MOPP 4	MOPP 3	MOPP 2	MOPP 1	MOPP 0	MOPP Ready
Indications	Attack with CBRN agents is imminent or has already. OR CBRN hazard is not fully characterized.	Attack with CBRN agents is probable or has already occurred.	Preattack. Attack with CBRN agents is likely.	Preattack. Attack with CBRN agents is possible. Time to achieve MOPP 4 from MOPP 1: ≤4 minutes	Preattack. Period of increased alert. Time to achieve MOPP 4 from MOPP 0: ≤8 minutes	Preattack.
Protection Provided	Highest degree of skin, eye, respiratory protection.	Used in areas where skin contact with liquids or vapors is nonhazardous. Highest degree of respiratory protection.	High degree of skin protection.	High degree of skin protection against persistent chemical agents.	None. Immediately. Equipment must be available within 5 minutes for putting on ("donning").	None
Respiratory Protection	Worn	Worn	Carried	Carried	Carried	Carried
Overgarment	Worn	Worn	Worn	Worn	Readily available	Can be issued within 2 hours.
Boots	Worn	Worn	Worn	Readily available	Readily available	Can be issued within 2 hours.
Helmet Cover	Worn	Worn	Worn	Readily available	Readily available	Can be issued within 2 hours.
Gloves	Worn	Readily available	Readily available	Readily available	Readily available	Can be issued within 2 hours.

Source: Personal Protective Equipment (PPE) in a Radiation Emergency - Radiation Emergency Medical Management (hhs.gov)

Table 4: Civilian PPE in a Radiation Emergency - Radiation Emergency Medical Management (hhs.gov)

OSHA/EPA Classification	Level A	Level B	Level C	Level D
Protection provided	Highest level of skin, eye, respiratory protection	Highest level of skin, eye, respiratory protection; lower level of skin protection.	Lower level of respiratory and skin protection. Adequate for radiation event response where other hazards have been determined not to be present.	Lowest level of respiratory and skin protection.
Indications	Identified or suspected hazards requiring maximal skins, eye, and respiratory protection. Working in confined areas where hazards have not been fully characterized.	Identified or suspected hazards requiring maximal respiratory protection. Working in atmospheres containing less than 19.5% oxygen. Lower-level skin hazard may be present.	Hazards have been identified. Hazards will not be absorbed by or adversely affect exposed skin. All criteria for using an air purifying respirator are met (i.e. concentrations of all airborne contaminants are known, appropriate, filters are available, oxygen levels are sufficient).	Atmosphere contains no known hazards. No or very low potential for unexpected respiratory or skin contact with environmental hazards.
Who should wear	First responders When identified or potential risk or biological, liquid or vapor chemical exposure exists	First responders When entering the most heavily contaminated radiation zones to rescue victims or protect valuable property necessary for public welfare.	First responders and first receivers. When caring for patients/victims likely to be contaminated with radiological material.	First receivers. When working in post decontamination areas should wear standard precautions PPE (per protocol)for infection control purposes. [3]

1. *EPA PPE information*
2. *OSHA PPE information*
3. *Standard precautions PPE and procedures used to prevent transmission of infections within healthcare settings provides adequate protection against low levels of radiological contamination that may be found in post decontamination areas of the hospital (e.g. emergency department and surgical suites). No formal PPE is required to be worn when delivering care to persons with high dose radiation exposure although reverse isolation procedures will need to be observed as neutropenia becomes prominent.*

APPENDIX B: RADIATION DETECTION STANDARDS & CONSIDERATIONS

The appendix provides information on the various technologies that can detect radiation and confirm the presence of contamination on personnel or in the environment. More information can be found at https://jacks.jpeocbd.army.mil/ No single device can detect all forms of radiation and no one device is useful in all situations. Radiation detection devices detect and measure the following: 1) specific types of radiation, (e.g., alpha, beta, gamma, neutron), 2) specific levels (or ranges) of radiation energy (in keV, MeV) 3) "Counts" per unit time (minute or second) 4) Roentgens (R) per unit time (e.g., milliroentgen per hour [mR/hr]) 5) cumulative dose (in units of gray or rad) 6) dose rate (in units of gray or rad per unit time).

Individual Dosimetry	
Individual dosimeters come in various types and sizes and are dependent on the manufacturer and specifications required by the end-user.	
AN/UDR-13 Radiac Set. NSN: 6665-01-407-1237 	The AN/UDR-13 is a compact, hand-held, or pocket-carried tactical dosimeter capable of measuring gamma dose and dose-rate from nuclear fallout. **AN/UDR-13 detection elements can give false positives, false negatives, and are not accurate for the measurement of radiation immediately following a nuclear detonation. Neutron damage to the device may cause subsequent false dose readings with temperature increases. If an AN/UDR-13 is the vicinity of a nuclear detonation (within 2 km) at the time of detonation, then that AN/UDR-13 should only be used for dose rate, not dose.
AN/PDR 75A Personal Dosimeter 	The Radiac Set AN/PDR-75 has the capability to monitor and record the exposure of individual personnel to gamma and neutron radiation. Each individual will be issued a PDR-75 dosimeter. This device, worn on the wrist, contains a neutron diode and a phosphate glass gamma detector. When determination of exposure is required, the dosimeter is inserted into a CP-696/PDR-75 reader, which then displays the cumulative neutron and gamma doses.

Detection Devices	
Radiation detection devices come in a different shapes and sizes with varying capabilities, which are available as an off-the-shelf solution for units.	
AN/VDR-2 Radiac Set/Monitor. NSN: 6665-01-222-1425 	The AN/VDR-2 is a tactical beta / gamma rate meter. It can be used to perform ground radiological surveys from vehicles or used as a hand-held instrument by individual soldiers. It can be used to determine the contamination level of personnel and the effectiveness of decontamination efforts.
FLIR (icx) IdentiFINDER LaBr3 	The IdentiFINDER LaBr3 is a Commercial Off The Shelf (COTS) item which is fielded to Special Purpose CBRN Consequence Management Units. The IdentiFINDER instrument is part of a family of hand-held digital gamma spectrometers. The IdentiFINDER CdZnTe (model # idF-UL-LGH) contains a gamma LaBr3 detector, a neutron 3He proportional counter tube and a high dose rate gamma detector in a handheld down range instrument.
FLIR IdentiFINDER R400 	Suitable for a wide variety of monitoring scenarios including all-purpose surveying, emergency response, and environmental monitoring. Gamma and Neutron Detection using NaI detector enables rapid isotope identification (ANSI N42.34 library) for threat determination; GM detector provides dose rate and total dose.

Detection Devices	
AN/PDR-77 Radiac Set. NSN: 6665-01-347-6100 	The AN/PDR-77 is used for nuclear weapons accident response, environmental-level measurement of radiological materials, and work area monitoring. The system incorporates an alpha probe, beta gamma probe, and x-ray probe.
RadEye B20-ER (Commercial) 	Continuous dose rate mode for frisking operation. Dose Range: Gamma Dose Rate: 0 to 100mSv/h (0 to 10 rem/h); Contamination: 0 to 500kcps Menu-driven user interface results in low training cost and immediate familiarity.

APPENDIX C: BIODOSIMETRY

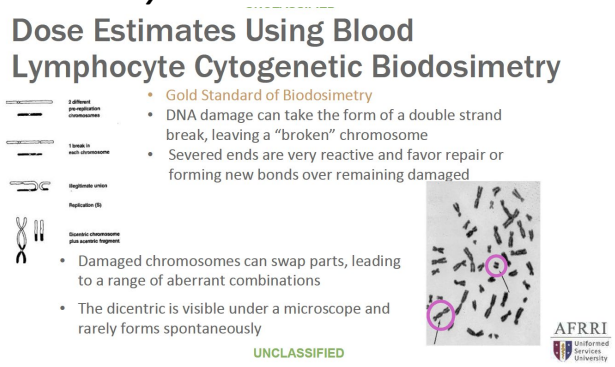
Clinical signs and symptoms are dose dependent. Therefore knowing early markers to estimate radiation dose in radiologically exposed patients can be very helpful. Radiation dose can be estimated using time to emesis, medical history, and serial blood cell counts. Medical history should include the circumstances of suspected exposure, location relative to the incident, sheltering, and any other pertinent exposure details, such as smell or taste of dust/smoke and dust/debris on skin, in addition to clinical symptoms.

If laboratory support is available, serial complete blood counts (CBC) are one of the most readily available and useful methods to characterize dose received. An initial CBC with differential followed by serial measurements three times a day for 2 to 3 days will facilitate determination of the slope of lymphocyte depletion. A drop in lymphocyte count by more than 50% in the first 48 hours indicates a potentially lethal exposure. If there was only exposure to ionizing radiation, time to emesis can be used in the absence of laboratory support or as an adjunct to lymphocyte count. Emesis **within 1 to 2 hours** of exposure carries a poor prognosis.

Early-phase signs and symptoms

Symptom	Severe ARS	Moderate ARS	Mild ARS
Vomiting Onset	Within 1 hour	1-4 hours	>4 hours
Vomiting per day	>6 worsening	3-6	1-2 resolving
Diarrhea	>6	<6	None
Headache	Severe	Mild	None
Fever	High	<101°F resolving	none

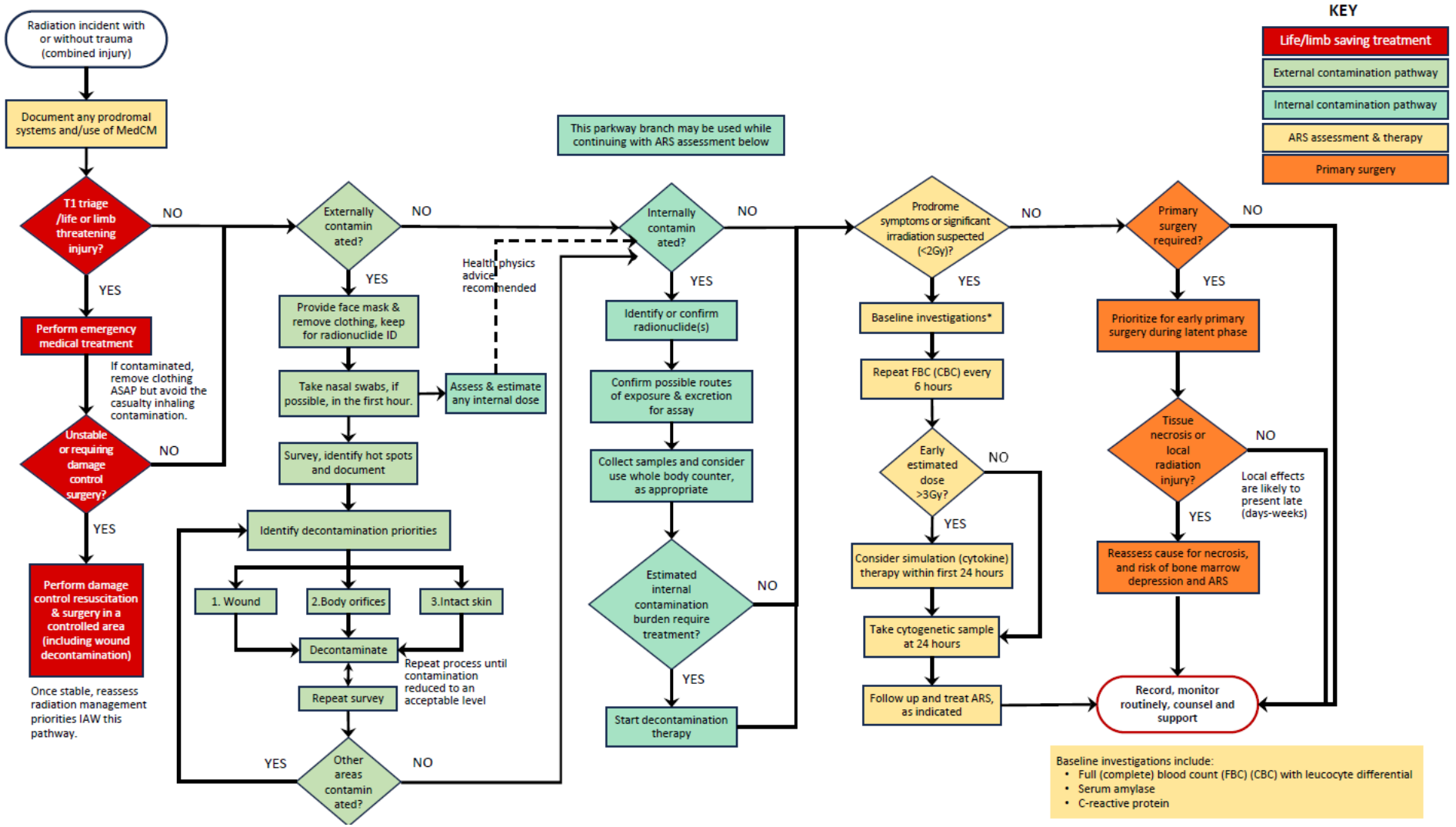
Dose estimates using blood lymphocyte cytogenetic biodosimetry



The chromosome-aberration cytogenetic bioassay (specifically lymphocyte dicentrics) is considered the gold standard in estimating dose. However, samples must be obtained after 24 hours of exposure, and results may not be available for 2 to 3 days, so time to emesis and lymphocyte counts remain the most useful tools in the initial assessment period. It is helpful to remember that if an individual has not vomited within 8 to 10 hours of exposure, it is unlikely he or she was exposed to a dose over 1 Gy. The Armed Forces Radiobiology Research Institute Biodosimetry Assessment Tool is a software package that can help providers assess exposure and guide therapy. The tool has a complimentary package for first responders called the First Responders Radiological Assessment Triage. These useful tools can facilitate optimization of a standardized framework for the response to nuclear or radiological incident.

The Department of Health and Human Services Radiation Emergency Management (REMM) webpage has interactive tools to assist with biodosimetry. These tools can be found at: https://remm.hhs.gov/ars_wbd.htm .

APPENDIX D: RADIATION CASUALTY CARE PATHWAY



Adapted from the REACT/TS Treatment Algorithm.

APPENDIX E: SUPPLEMENTAL CBRN DOCUMENTATION FORM

JTS CBRN 3 Supplemental Clinical Documentation Form

EXPOSURE INCIDENT

Time exposure occurred ____ Duration of exposure ____ ◯ Check if unknown

Radiation type/agent type (if known): ____

PPE worn? ◯ YES ◯ NO

Type of PPE if worn ____

Did the patient vomit after the exposure? ◯ YES ◯ NO

If yes, how long after the exposure did the patient vomit? _____ minutes

ARRIVAL TEMPERATURES

Note 1-hour temperatures for first 4 hours: _____ _____ _____ _____

Note 2-hour temperatures for next 16 hours: _____ _____ _____ _____

_____ _____ _____ _____

Comments

TREATMENT TEAM INFORMATON

Facility/Location ____ Unit ____

Team type ____ Split team? ◯ YES ◯ NO

RN/Medic name ____ Signature Field ____ Date ____

Provider name ____ Signature Field ____ Date ____

PATIENT INFORMATION

Patient last name ____ First name ____ MI ____ DOB ____ Age ____

Sex ◯ M ◯ F MOS/AFSC/NEC ____ Patient deployed unit ____

20 Aug 2024, v1.0

APPENDIX F: CLASS VIII MEDICAL MATERIEL

The JTS CPG for managing radiation exposure in nuclear events outlines the necessary medical supplies and equipment to support patient care effectively.

Personal Protective Equipment (PPE)

1. Full-body protective suits with hood and gloves
2. Radiation dosimeters (personal and area monitors)
3. Respiratory protection (P100 respirators, N95 masks, or PAPRs with HEPA filters)
4. Lead aprons for personnel, if required based on exposure risk
5. Eye protection (goggles or face shields)
6. Disposable boot covers

Decontamination Supplies

1. Portable decontamination showers
2. Water-resistant mats and containment pools
3. Mild soap and detergent solutions for skin decontamination
4. Soft brushes and sponges
5. Forceps and pickups – Various sizes
6. Irrigation solution (normal saline, sterile water)
7. Absorbent towels and sheets (disposable)
8. Waste disposal bags (hazardous waste-specific bags)
9. Radiation-contaminated waste containers

Monitoring and Assessment Tools

1. Portable radiation detectors (e.g., Geiger counters, scintillation detectors)
2. Contamination monitors (e.g., hand and foot monitors)
3. Whole-body counters for radiation exposure assessment
4. Portable gamma spectrometers (for isotopic identification)

Medications for Radiation Sickness

1. Potassium iodide (KI) tablets (for thyroid protection)
2. Prussian blue (for cesium and thallium contamination)
3. Calcium or zinc-DTPA (for plutonium, americium, and curium contamination)
4. Anti-nausea medications (ondansetron, promethazine)
5. Pain management (opioids, NSAIDs)
6. Colony-stimulating factors (filgrastim, pegfilgrastim) for bone marrow support
7. Antibiotics (broad-spectrum coverage, adjusted for neutropenia)
8. Antidiarrheal medications

Supportive Care Supplies

1. Intravenous (IV) fluids (normal saline, lactated Ringer's solution)
2. Electrolyte replacement solutions
3. Blood products and transfusion supplies (if available)
4. Nutritional support (oral rehydration solutions, parenteral nutrition kits)
5. Oral rehydration salts (ORS)

Burn and Wound Care Supplies

1. Sterile dressings (gauze, non-adherent, hydrocolloid)
2. Antimicrobial ointments (silver sulfadiazine, bacitracin)
3. Burn care kits
4. Sterile irrigation fluids
5. Surgical debridement instruments (scalpels, forceps)
6. Suturing supplies (sutures, staplers, stapler removers)

Monitoring Equipment for Patient Care

1. Blood pressure cuffs (manual and automated)
2. Thermometers (digital and infrared)
3. Pulse oximeters
4. Cardiac monitors (portable EKGs, defibrillators)
5. Point of care laboratory testing with ability to do complete blood counts.

Other Essential Supplies

1. IV tubing sets and administration kits
2. Syringes, needles, and catheters
3. Waste disposal systems for contaminated materials
4. Stationery for documentation (contamination logbooks, patient assessment forms)
5. Communications equipment (for command and control during mass casualty events)

For additional information including National Stock Number (NSN), please contact dha.ncr.med-log.list.lpr-cps@health.mil

***DISCLAIMER:** This is not an exhaustive list. These are items identified to be important for the care of combat casualties.*

APPENDIX G: TELEMEDICINE / TELECONSULTATION

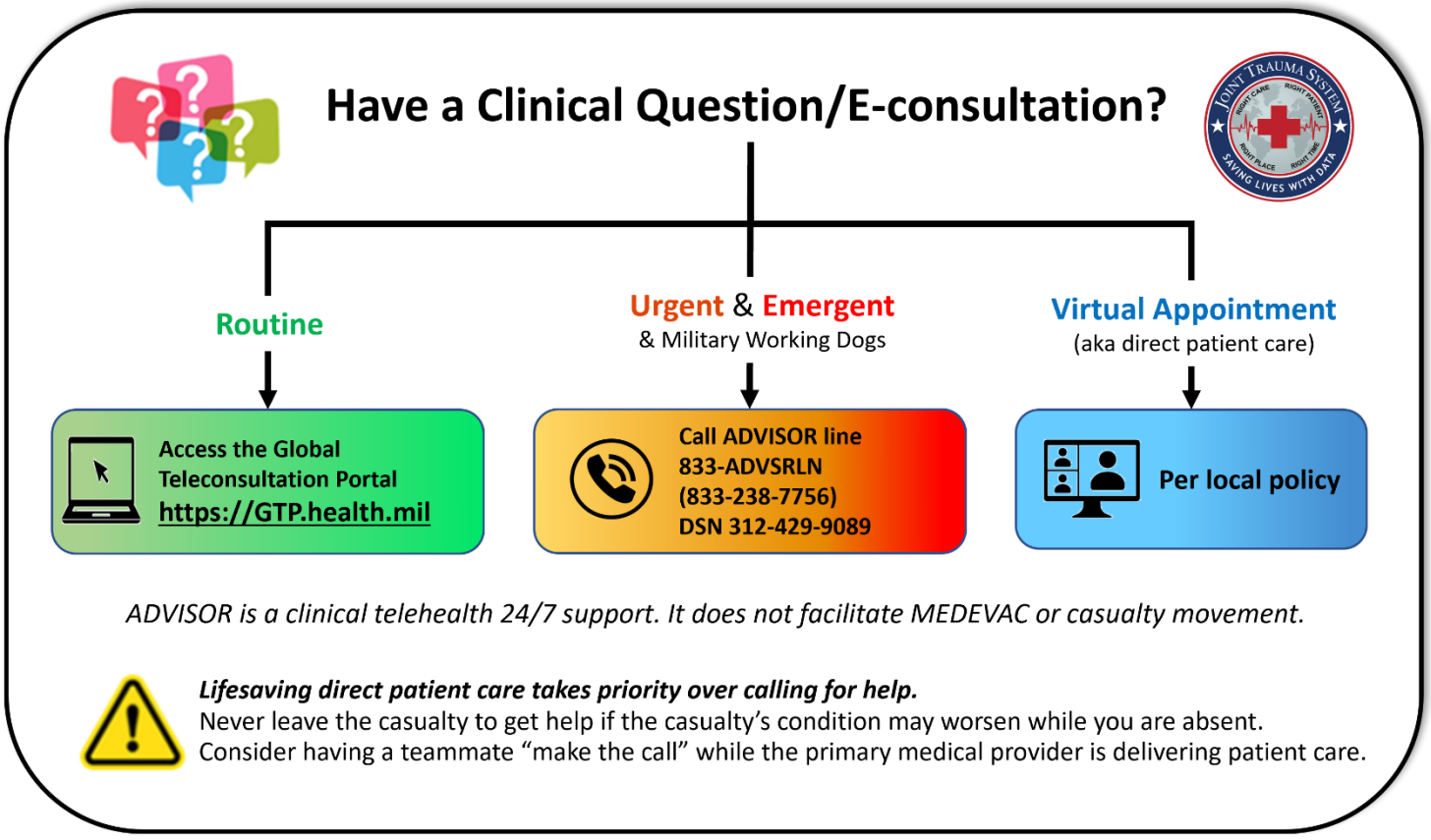


Illustration by Raymond Samonte

Global Teleconsultation Portal: https://GTP.health.mil

APPENDIX H: INFORMATION REGARDING OFF-LABEL USES IN CPGS

PURPOSE

The purpose of this Appendix is to ensure an understanding of DoD policy and practice regarding inclusion in CPGs of "off-label" uses of U.S. Food and Drug Administration (FDA)–approved products. This applies to off-label uses with patients who are armed forces members.

BACKGROUND

Unapproved (i.e. "off-label") uses of FDA-approved products are extremely common in American medicine and are usually not subject to any special regulations. However, under Federal law, in some circumstances, unapproved uses of approved drugs are subject to FDA regulations governing "investigational new drugs." These circumstances include such uses as part of clinical trials, and in the military context, command required, unapproved uses. Some command requested unapproved uses may also be subject to special regulations.

The inclusion in CPGs of off-label uses is not a clinical trial, nor is it a command request or requirement. Further, it does not imply that the Military Health System requires that use by DoD health care practitioners or considers it to be the "standard of care." Rather, the inclusion in CPGs of off-label uses is to inform the clinical judgment of the responsible health care practitioner by providing information regarding potential risks and benefits of treatment alternatives. The decision is for the clinical judgment of the responsible health care practitioner within the practitioner-patient relationship.

ADDITIONAL PROCEDURES

Balanced Discussion

Consistent with this purpose, CPG discussions of off-label uses specifically state that they are uses not approved by the FDA. Further, such discussions are balanced in the presentation of appropriate clinical study data, including any such data that suggest caution in the use of the product and specifically including any FDA-issued warnings.

Quality Assurance Monitoring

With respect to such off-label uses, DoD procedure is to maintain a regular system of quality assurance monitoring of outcomes and known potential adverse events. For this reason, the importance of accurate clinical records is underscored.

Information to Patients

Good clinical practice includes the provision of appropriate information to patients. Each CPG discussing an unusual off-label use will address the issue of information to patients. When practicable, consideration will be given to including in an appendix an appropriate information sheet for distribution to patients, whether before or after use of the product. Information to patients should address in plain language: a) that the use is not approved by the FDA; b) the reasons why a DoD health care practitioner would decide to use the product for this purpose; and c) the potential risks associated with such use.